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ATMOSPHERIC EMISSIONS FROM THE ASPHALT INDUSTRY

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The report summarizes the air pollution problem of the asphalt industry--hot-mix asphalt plants and roofing manufacture--emphasizing particulate emissions. It outlines industrial processes, types and sources of pollutant emissions, and current and required controls. Particulates are the principal emission from the industry; sulfur oxides, nitrogen oxides, odors, and hydrocarbons are emissions of minor importance. Approximately 200,000 metric tons of these pollutants (except for odor, per se) were emitted in the U.S. in 1968, with substantial control only for particulates. In spite of developed controls, the industry still has air pollution problems. Emitted pollutants contribute to a dense and foggy fume and cause most of the public's complaints. Particulates can be controlled by wet or dry methods (or a combination of the two), by fabric filters, or by baghouses. Emissions of sulfur oxides, nitrogen oxides, and hydrocarbons are not significant qualitatively, but each contributes to the odor and smog problems and should be controlled. Control devices can be used on asphalt plants. Electrostatic precipitators are not usually considered because of their initial cost and rather high volume. Control methods are available for the principal pollutant, particulates; however, as in many other industries, available controls are often not being installed.

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INTRODUCTION

The asphalt industry, with sales revenues approaching $2 billion in 1970, is economically among the leading U. S. industries.

Demands for asphalt and asphaltic products have increased immensely as home building, industrial activity, and highway construction have increased. Increased demands for the past 3 years are shown in Table 1.[1]

The production data do not include imports, exports, or fluctuations in year-end stocks. The shipments data include, in addition to refinery production and imports, various emulsifiers and blenders.[1]

The asphalt industry is divided into two segments: hot-mix asphalt plants and roofing manufacture. Major sources of emissions from the hot-mix plants are the rotary drier, fuel burners, and truck transportation; lesser sources are the elevators, screens, heating system, storage bins, and loading facilities. The major sources of emissions from roofing manufacture are the "blowing" stills and saturators. Factors contributing to these emissions include ash and sulfur content of the fuel oil used, control equipment and methods used, and the efficiency of blowing operations.

Table 1. DEMAND FOR ASPHALT AND ASPHALTIC PRODUCTS

	1969		1970		1971[a]	
Category	Metric tons (000)	Short tons (000)	Metric tons (000)	Short tons (000)	Metric tons (000)	Short tons (000)
Production	22,377	24,671	24,185	26,665	25,898	28,553
Shipments:	25,538	28,156	26,949	29,712	27,869	30,727
Paving	19,349	21,333	21,400	23,594	22,176	24,450
Roofing	3,701	4,080	3,853	4,248	4,011	4,422
Others	2,488	2,743	1,696	1,870	1,682	1,855

[a]Preliminary

Although control methods have been developed for some of the pollutants, the asphalt industry still has air pollution problems. The pollutants emitted contribute to a dense and foggy fume and cause a majority of the public's complaints. Progress has been made in controlling particulates, with the cost partially offset by using the recovered aggregate. Particulates can be controlled by wet or dry methods (or a combination of the two), by fabric filters, or by baghouses. The emissions of SO_2, NO_x, and hydrocarbons are not significant qualitatively, but each contributes to the odor and smog problems. These pollutants should be controlled.

The trade organizations and equipment manufacturers related to the asphalt industry have collaborated to develop equipment and technology for controlling, or at least reducing, all pollutants from the plants on a limited scale. That smaller independently owned plants will be hard pressed financially to install this expensive equipment has delayed the installation of the necessary controls; however, since performance standards for emissions are to be promulgated, plants without control equipment will be required to make the necessary installations.

The estimated particulate emissions from each segment in 1968 were 182,307 metric tons (201,000 short tons) from the hot-mix asphalt plants and 15,419 metric tons (17,000 short tons) from the roofing manufacture, or a total of 197,726 metric tons (218,000 short tons) from the two segments of the asphalt industry. The emission factors are estimated to be 18 kg/0.91 metric ton (40 lb/short ton) from the hot-mix plants and 4 kg/metric ton (8 lb/short ton) from the roofing manufacture.[2]

Asphalt is one of the oldest construction materials. Some of the earliest records tell of its use to preserve the dead, to waterproof material, as a mortar for stone-built structures, and as a "cement" for roads. Asphalts used by ancient peoples were the "natural" asphalts found in pits and lakes.[3]

The development of the petroleum industry, beginning late in the nineteenth century, provided the processes of refining and producing asphaltic materials in huge quantities and in various types and grades under carefully controlled operating conditions. Technology and research also developed and furthered the use of these products. Today, their various applications number literally in the thousands.

About 70 percent of the asphalt production is used for paving. The first effective asphalt pavement was laid in France in 1810; within a decade, asphalt pavements were accepted throughout the United States as an excellent road surfacing material.(4)

In addition to their use in pavement surfaces for highways and airfields, asphaltic products apply to other features of highway construction: stabilizing the upgrading of soils and aggregates in base construction, shoulder treatments, undersealing and joint sealing of Portland cement concrete slabs, and mulch treatment of cut-and-fill slopes.

In recent years, asphalt has been used extensively in various types of hydraulic structures. Hot asphalt paving mixes are used to face the upstream side of large dams and to line reservoirs, canals, and rivers for the prevention of both erosion and, in some cases, seepage losses. Prefabricated asphaltic membranes, asphalt-fiber panels, and sprayed asphaltic materials are also used to line reservoirs and canals. Hot-mix sand asphalt is used in building groins both to prevent beach erosion and to build up eroding shore lines. Asphalt mixes are also used in storm-water channels where rapid runoff of debris-laden water normally results in severe erosion.(3,4)

As a roofing material, asphalt far exceeds all other types combined. Asphalt shingles are prepared by impregnating roofing felt with an asphalt saturant; after both sides of the felt are coated with a harder tougher asphalt, mineral granules are embedded in the surface of one side, and the material is cut into shingles or strips. Two types of asphalt roll roofing are in common use: smooth

and mineral surfaced. These, too, are asphalt-saturated felts, coated with a harder grade of asphalt. Asphalt built-up roofing is composed of several layers of asphalt-saturated felt applied to a flat or sloping roof deck. Asphalt is applied between the felt layers for adhesion. A flood coat of asphalt is applied over the top layer and usually covered with gravel or slag.(3)

Asphalts are used extensively for industrial and specialty purposes, including battery cases, automobile undercoating, tire manufacture, a wide variety of waterproofing and dampproofing applications, as a base for paints and lacquers, printing inks, and in the manufacture of floor coverings and building insulation.(4)

Asphalt used in making the hot mix for paving and in air-blowing for roofing material is normally prepared at refineries; however, some is found in naturally occurring deposits. Over 90 percent of the asphalt used in the United States is recovered from crude oil, with the method depending on the type of crude oil being processed. The "crude" is distilled at atmospheric pressure to remove the lower boiling materials such as gasoline, kerosene, diesel oil, and gas oil. Nondistillable asphalt may then be recovered from selected topped crude by vacuum distillation.

A typical vacuum distillation unit is shown in Figure 1.(3) This unit uses a heater, preflash tower, vacuum tower, and auxiliary equipment for processing the topped crude to yield the desired product. Distillation of topped crude under a vacuum removes oil and wax as distillates, leaving the asphalt as a residue. The asphalt properties are controlled by the amount of distillates removed: the more removed, the harder the asphalt. Many grades are produced depending on their ultimate uses and local specifications. The grades are based on such properties as softening point, penetration, and ductility. Asphalt prepared from petroleum is sometimes referred to as artificial asphalt: it is dark-brown to black, solid or semi-solid, and used as-is for various types of paving or processed further for building materials.(3)

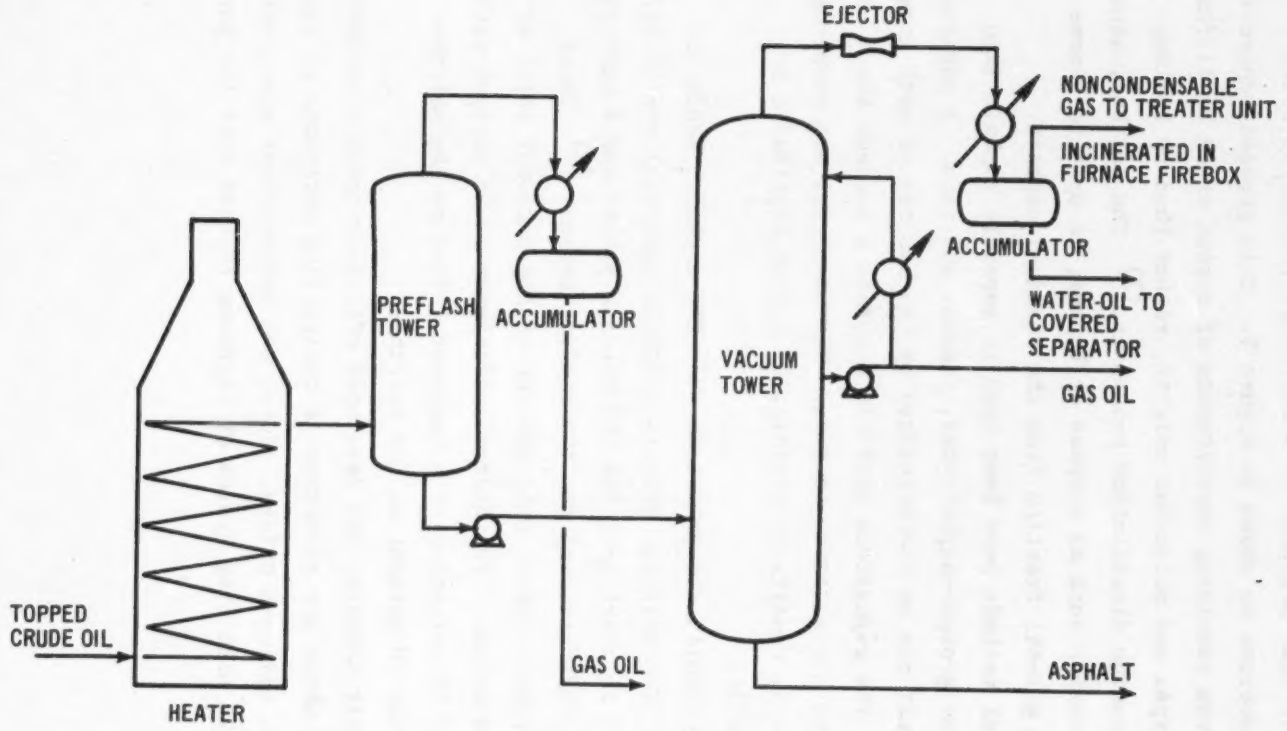

Figure 1. Flow diagram of vacuum distillation unit.

Asphalt is also produced as a secondary product in solvent extraction processes as shown in Figure 2. This process separates the asphalt from remaining constituents of topped crude by differences in chemical types and molecular weights, rather than by boiling points as in vacuum distillation processes.[3] The solvent, usually a light hydrocarbon such as propane or butane, is used to remove selectively a gas-oil fraction from the residual asphalt.

Analytical methods have been used to separate asphalt into three component groups--asphaltenes, resins, and oils. A particular grade of asphalt may be characterized by the amounts of each group it contains. The asphaltene particle provides a nucleus about which the resin forms a protective coating. The particles are suspended in an oil that is usually paraffinic but can be naphthenic or naphthenoaromatic.

The most significant pollutant from the asphalt plants is particulates. The emission factors (without controls) are 18 kg/0.91 metric ton (40 lb/short ton) for the hot-mix plants and 4 kg/0.91 metric ton (8 lb/short ton) for the roofing segment.[2] These quantities represent about 0.65 percent of the national total of particulate emissions. The control efficiency is 96 percent without a baghouse and 99 percent with a baghouse filter on the hot-mix plants and about 50 percent on the roofing.

The asphalt industry has developed efficient control technology and equipment which are effective in controlling emissions of particulates. Sulfur oxides, nitrogen oxides, odors, and hydrocarbons are controlled somewhat in the scrubbing system or baghouse filters used for particulate control.[5]

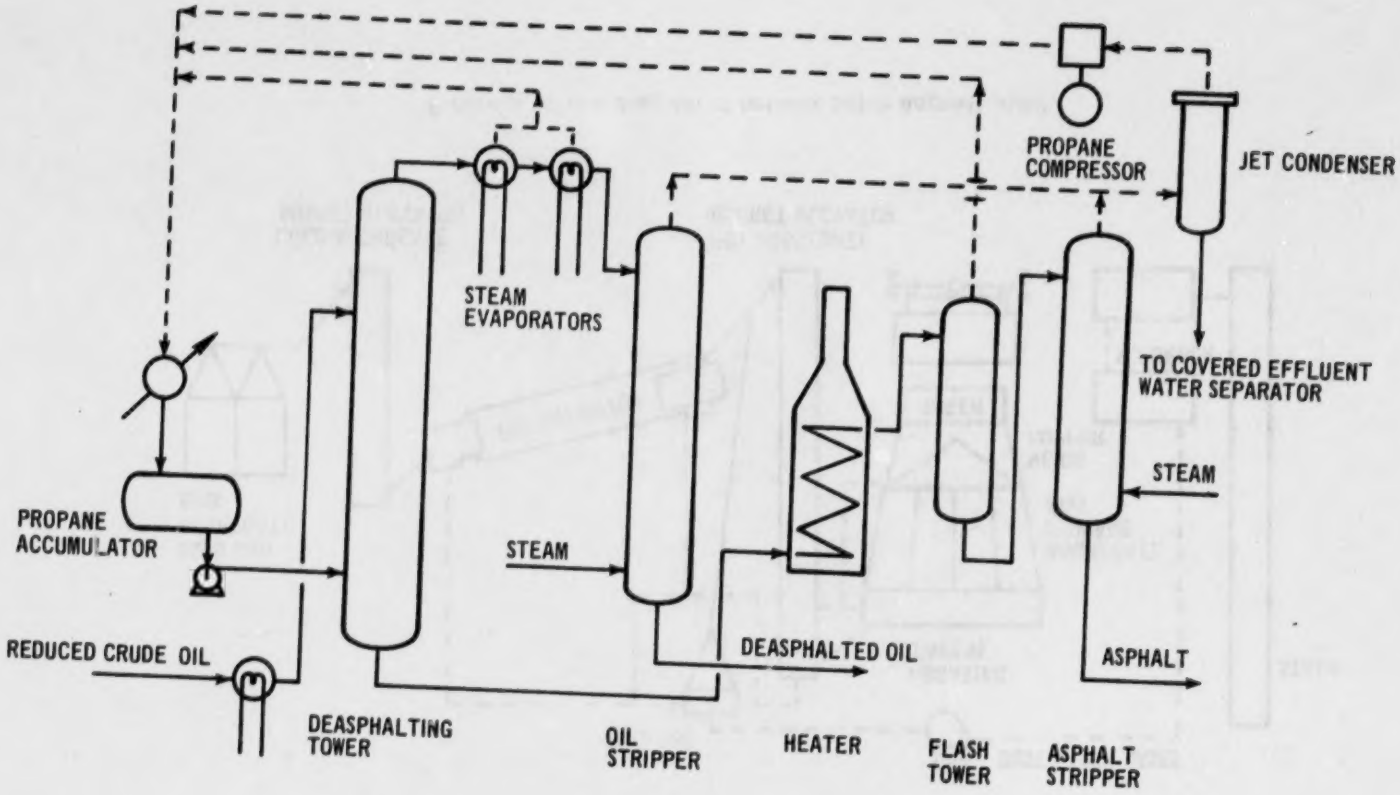

Figure 2. Flow diagram of propane deasphalting unit.

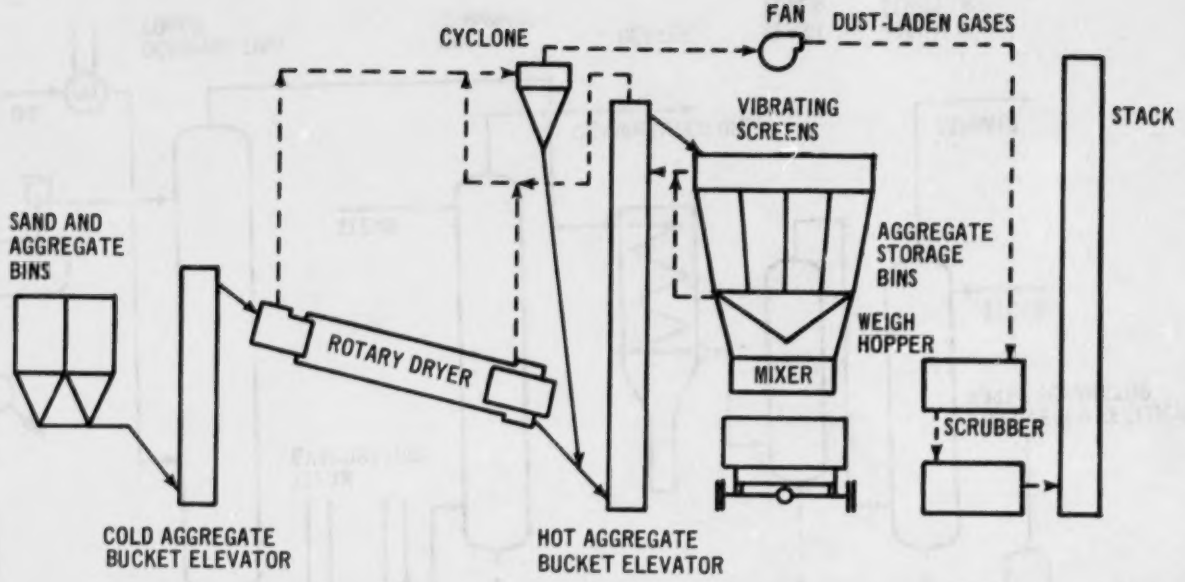

Figure 3. Flow diagram of hot-mix batch asphalt plant.

THE ASPHALT INDUSTRY

The manufacturing processes of the asphalt industry should be considered in order to understand the air pollution problems of the industry. Basically, the industry is divided into two segments or divisions: hot-mix asphalt plants and roofing manufacturing. Each will be discussed separately.

HOT-MIX ASPHALT PLANTS

The asphalt hot-mix segment is characterized by a large number of small firms: many have only one plant; and others have two or three.[6] Most of the firms are small in comparison with the giant firms of some of the other industries. Since paving asphalt must be delivered hot to the job site, plants are limited to their area of operations; although some have been designed to be moved from site to site at a small cost, stationary plants are set up for efficient operation at a permanent location.

The road paving material commonly called asphalt (referred to as hot-mix asphalt) is a heated mixture of crushed stone aggregate, sand, and asphalt. It is commonly produced by a batch process with an average production rate of 91-182 metric tons (100-200 short tons) per hour, per plant. There are currently 4500 asphalt hot-mix plants operating in the United States.[7]

Hot-mix asphalt plants are classified either as batch mix or continuous mix. Both types have the same flow up to measuring the hot aggregate from the bins into the mixer.[8]

Figure 3, a flow diagram for hot-mix batch asphalt plant, shows equipment and sources of emissions for this process.[3] The equipment usually consists of:

1. A rotary drier for removing moisture from the sand and crushed stone.
2. Conveyors for loading the drier and removing the dried material to the storage bins.
3. Mixing and weighing equipment for the proper proportioning of the asphalt with the sand and aggregate.

4. Vibrating screens for separating the aggregate.
5. A fan and cyclone for exhausting the fines and dust from the drier.

The actual process consists of:[8]

1. Conveying proportioned quantities of cold aggregate to a drier.
2. Heating and drying the aggregate at 121 to 177°C (250 to 350°F).
3. Screening and classifying hot aggregate and storing it in hot bins.
4. Heating the asphalt to 135 to 165°C (275 to 325°F).
5. Measuring and mixing the asphalt in proper proportions.
6. Delivering the hot mixture to trucks which haul it to the paving site.

Asphalt paving mixes may be produced from a wide range of aggregate combinations, each having particular characteristics and suited to specific design and construction uses. Aside from the amount and grade of asphalt used, the principal characteristics of the mix are determined by the relative amounts of coarse aggregate (retained on a No. 8-mesh sieve), fine aggregate (passing a No. 8-mesh sieve), and mineral dust (passing a No. 200-mesh sieve).[3]

Aggregates of all sizes up to 6 cm (2-1/2 inches) in diameter are used in hot-mix asphalt paving. The coarse aggregates usually consist of crushed stone, slag, gravel, decomposed granite (or other material occurring naturally in a fractured condition), or highly angular material with a pitted or rough surface texture. The fine aggregates usually consist of natural sand. All aggregates must be free from coatings of clay, silt, or other objectionable matter and meet tests for soundness (ASTM Method C88) and wearability (ASTM Method C131).[3]

Mineral filler (dust) is used in some types of paving. It usually consists of finely ground particles of crushed rock, limestone, hydrated lime, Portland cement, or other nonplastic mineral

matter. A minimum of 65 percent of this material must pass a No. 200-mesh sieve.

Asphalt, a solid at ambient temperature, is usually used as a liquid at 135 to 163°C (275 to 325°F). One property measurement used in selecting an asphalt is penetration, determined by ASTM Method D5. The most common penetration grades used in asphalt paving are 60 to 70, 85 to 100, and 120 to 150. The grade used depends upon the type of aggregate, the type of pavement, and the climatic conditions.

Typical paving mixes are given in Table 2.

Table 2. TYPICAL PAVING MIXES

Paving mix designation		Maximum size[a] aggregate normally used	
Type	Description	Surface and leveling mixes	Base, binder, and leveling mixes
I	Macadam		2-1/2 in.
II	Open graded	3/8 to 3/4 in.	3/4 to 1-1/2 in.
III	Coarse graded	1/2 to 3/4 in.	3/4 to 1-1/2 in.
IV	Dense graded	1/2 to 1 in.	1 to 1-1/2 in.
V	Fine graded	1/2 to 3/4 in.	3/4 in.
VI	Stone sheet	1/2 to 3/4 in.	3/4 in.
VII	Sand sheet	3/8 in.	3/8 in.
VIII	Fine sheet	No. 4	No. 4

[a]For the reader's convenience, non-metric units are used here, in spite of EPA's general policy of using metric units. To convert these units to metric (cm), multiply each by 2.54.

1. The continuous-mix plant transfers a preblended mixture of the dried and graded aggregate from the hot bins to the mixer, using a bucket elevator.[8] (Dry mixing is not required, as it is in the batch plant.)

2. The hot asphalt is sprayed onto the aggregate continuously, as it falls into the mixer.

3. The mixing time is altered by the volume of the mixer. This is done by raising or lowering a dam (adjustable weir) on the discharge end of the mixer.[8]

Mixing time can be varied without changing the hourly tonnage output by varying the height of the adjustable dam. A typical continuous plant is shown in Figure 4 with potential sources of pollutants.[9]

Uses for asphalt and its products include:

1. Paving -- Highways, streets, parking areas, driveways, service station lots, sidewalks, railroad beds and crossings, airfield areas, and seal coats.

2. Hydraulics -- Linings for canals, drainage ditches, and reservoirs, and erosion control along rivers and lakes.

3. Recreational -- Tennis courts, swimming pools, and playgrounds.

4. Roofing -- Shingles and smooth and mineral-surfaced roll roofing.

5. Miscellaneous -- Farms (feed lots, barn lots, and floors), loading areas, and pipe covering and coating.

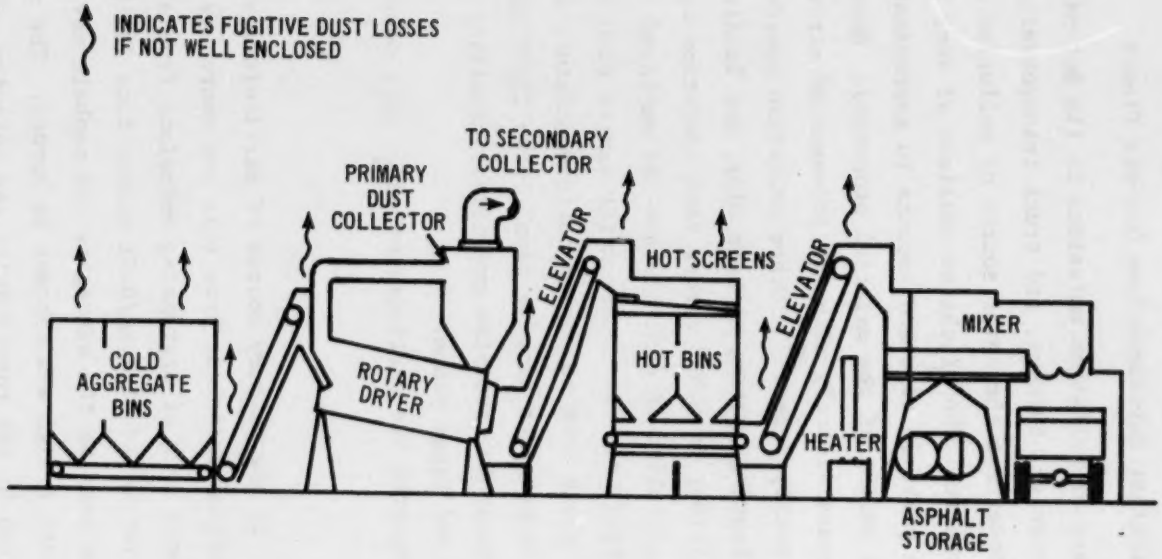

Figure 4. Flow diagram of continuous-mix asphalt plant.

Major Sources of Pollutant Emissions from Hot-Mix Plants

The major sources of pollutant emissions in the hot-mix asphalt plant are the rotary drier, burners, and truck transportation. Emissions from the aggregate drier are the chief source of pollution in the asphalt hot-mix operation. The discharge consists of very fine dust under a No. 200-mesh particle size and amounts to approximately 5 percent of the total weight of the material processed. Moreover, the total emissions increase directly with any increase of air velocity passing through the rotary drier.[8] Other pollution sources are the elevators, screens, heating system, storage bins, and loading and transportation facilities; in other words, each operation can be a potential source of pollution if controls are not employed. The quantity of dust emitted from the rotary drier varies with the operations. The hot gases from the drier contain moisture from the aggregate and, with temperature ranging from 177 to 232°C (350 to 450°F), absorb odors and hydrocarbons from the operations resulting in the formation of a dense and foggy plume.

The pollutants emitted are particulates, SO_2, NO_x, odors, and hydrocarbons.[6,8]

Particulates

The rotary drier is the primary source of particulate emissions. The estimated uncontrolled emissions from this one source is 15 kg/0.91 metric tons (32 lb/short ton) of aggregate; emissions from all other points of the operation are estimated at 4 kg/0.91 metric tons (8 lb/short ton).[2]

The fuel used for heating the aggregate and asphalt may emit some particulate if fuel with a high ash content is burned. The quantity emitted will be affected by the rotary drier gas velocity, the type of fuel used (gas or oil), and the efficiency of the combustion process. Burning oil in the drier will increase particulate emissions by an estimated 2 kg/hr (5 lb/hr) more than with gas.[3]

Sulfur Dioxide

SO_2 emissions are from the combustion process when fuel oil is burned to dry the aggregate or heat the asphalt. The amount actually emitted can be decreased by water scrubbers or the type of aggregate being dried (limestone or marble). The emission factor is not available.

Nitrogen Oxides

NO_x is emitted from the combustion process only. The quantity is not available.

Odors

There are three potential sources of odors in a hot-mix plant: hot asphalt, inefficient burner operation, and the fuel oil used on truck beds to prevent the asphalt from adhering. The odors from the asphalt and fuel oil could cause problems in urban areas, but normally do not. The efficiency of the combustion process will determine the emission of aldehydes and odoriferous organic acids. Quantitative data are not available.

Hydrocarbons

Hydrocarbons are emitted from the combustion process, but in insignificant quantities: estimated to be 64 kg/1600 hectoliters (140 lb/1000 bbl) of fuel oil burned.

Asbestos

Asbestos is now being added to hot-mix used for highways and streets to develop non-skid surfaces. Information on this emission is not available.

Available Control Methods for Hot-Mix Plants

Without question, asphalt mixing plants will emit pollutants if operated without some controls.[9] These plants are numerous and are located in residential communities, industrial areas, rural areas, and even in arid desert areas. Those located in the residential areas are sources of many nuisance complaints.

Practically any control device can be used on asphalt plants. Electrostatic precipitators are not usually considered because of their initial cost and their rather large volume. Control methods are available for the principal pollutant from asphalt plants, particulates. However, as in many other industries, available control equipment is often not being installed.

Particulates

Control equipment for particulates falls into two categories, wet or dry. In some plants both methods are used.[8] Until very recently, the accepted method of controlling emissions from the drier consisted of wet collectors installed in series with conventional dry collectors, such as simple cyclones. The wet collectors are usually the spray impingement type (with collecting efficiencies of 90 - 95 percent) or the high-energy, high-efficiency venturi type (with efficiencies upward of 95 percent). However, wet collector performance in many instances fails to meet the Equivalent Opacity regulations that are often written into metropolitan area codes. The wet process uses water to wet the dust particles; recovering them as a sludge creates a water disposal problem. Since the efficiency of the wet scrubber is only about 95 percent, the emissions may not meet local requirements. The dry process employs cyclones and multiple cyclones to reduce the emissions to the required local control level. If necessary, some plants use a baghouse filter to obtain the necessary limit. The materials recovered in the dry process can be used in the hot-mix as aggregate. Without the baghouse, this control method is about 95 percent efficient; with the baghouse, efficiency is about 99 percent.

Usually the gas from the drier and the emissions from other sources in the asphalt plant are collected in a vent line and sent through a cyclone dust collector.

All wet collectors, regardless of kind, carry with them the problem of sludge disposal. Federal and state water pollution regulations prevent disposal to natural drainage systems. This water

may carry odors leached from the aggregate raw material drier. Recirculation of pond water, as it is sometimes called, tends to increase the odor potential from this phase.

Up to a few years ago, dry collectors for asphalt mixing plants consisted of cyclones and multiclones, which yielded efficiencies of approximately 75 - 80 percent at best and did not collect the greater percentage of the dust (200 microns or less). These dry collectors were modified into primary collectors, followed by the installation of the more efficient wet collectors in series with them, thereby increasing the overall efficiency to above 95 percent. As control regulations become more severe fabric filters or baghouses will be required.

Inherently, the two main factors hindering optimum collection efficiencies of any baghouse are temperature and moisture. Both of these conditions are prevalent in the exhaust stream from an asphalt hot-mix plant. Latest technology has proven that properly designed bag collectors can comply with any of the stringent regulations. Collection efficiencies of over 99 percent can be achieved and "clear stacks" are not uncommon. Costwise, the baghouse will range 20-30 percent higher than the cyclone and/or scrubber. Recovered dust is returned to the process. Savings realized from the recovery of these fines offset the cost of the equipment.

Control Technology Needed for Hot-Mix Plants

SO_2 and NO_x are emitted in such insignificant quantities that controls are not employed. Hydrocarbon emissions, which can cause a serious odor problem,can be reduced slightly by wet scrubbers and baghouse filters. At present they do not present pollution problems.

Research work is needed to develop controls for odors (and perhaps for hydrocarbons) from the potential emission sources. Improvements of controls for these two pollutants would reduce public complaints. Recently asbestos has been added to the weigh hopper along with the aggregates, hopefully to develop non-skid surfaces on

highways and streets. There could be some health hazards attached to asbestos handling and emissions. Emission factors for this process should be developed.

ASPHALT ROOFING MANUFACTURE

The manufacture of asphalt roofing felts and shingles involves saturating a fiber medium with asphalt by dipping and/or spraying. While not always done at the same site, an integral part of the operation is preparing the asphalt saturant.[3] This preparation consists of oxidizing the asphalt by bubbling air through liquid asphalt for 8-16 hrs at 221 to 260°C (430 to 500°F). This operation is known as "blowing."

Airblowing is a dehydrogenation process. Oxygen in the air combines with hydrogen in the oil molecules to form water vapor. The progressive loss of hydrogen results in polymerization of the asphalt to the desired consistency.[3] Although blowing may be continuous, it is usually carried out batch-wise in horizontal or vertical stills equipped to steam-blanket the charge for safety. Vertical stills are more efficient because of longer air/asphalt contact time. The asphalt is heated to 149 to 205°C (300 to 400°F) either by an internal fire-tube heater or by circulating the charge material through a separate tube-still before the injection of 0.14-0.57 m^3 of air/min/0.91 metric ton (5-20 ft^3 of air/min/short ton) of asphalt. Little additional heat is necessary: the reaction becomes exothermic.[3]

Figure 5 is a flow diagram of airblown asphalt manufacture (batch process).

Pollutants from the airblowing stills include particulates, sulfur and nitrogen compounds, hydrocarbons, odors, and water vapors.

The time required for blowing depends on the desired properties of the saturant. It had been the practice to blow the asphalt in horizontal stills where the material loss ranges from 3 to 5 percent. Most of this material is recovered by venting the exhaust gases through oil knockout tanks which are an integral part of the process.

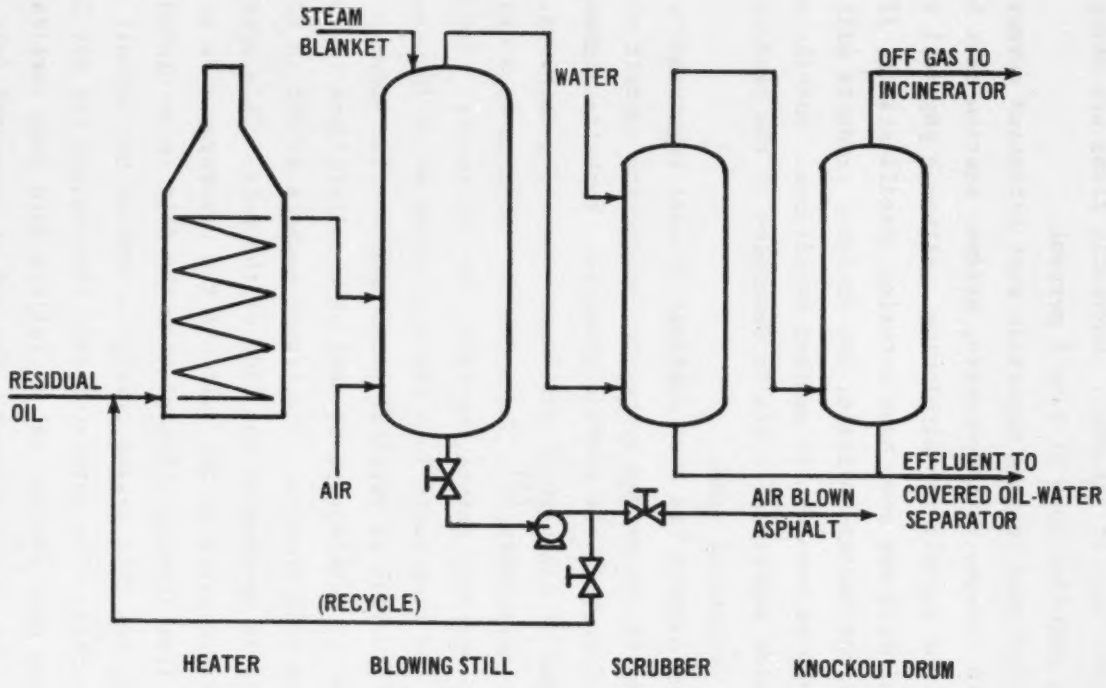

Figure 5. Flow diagram of airblown asphalt manufacture (batch process).

The recovered liquid is either reprocessed or used as fuel oil. The gas may be charged to afterburners. In horizontal stills,0.95 metric tons (1.05 short tons) of asphalt is required to produce 0.91 metric tons (1.00 short ton) of saturant. Currently firms are using vertical stills with a material loss of 1 to 2 percent.

Because finished roofing materials must withstand severe weather conditions and changes in temperature, extreme caution must be taken in selecting the asphalt for airblowing. Although physical tests of the unblown asphalt may meet manufacturing specifications, if the airblown saturant becomes brittle, the finished products will crack and deteriorate on exposure to weather conditions. Manufacturers may have accelerated weathering tests to determine if the products are suitable for industrial uses.

After the asphalt has been airblown to meet requirements, it is transferred to the second operation: saturating asphalt roofing felt for manufacturing the roofing products. Asphalt-saturated felt is manufactured in high-speed, continuous-operating machines, referred to as asphalt saturators.[3] The saturator consists of a dry looper, asphalt spray section, saturating tank, and wet looper. The felt is continuously fed from rolls into the dry looper where it passes over rollers into a series of vertical loops used as live storage in the process to permit maintenance of feed at a uniform rate to the saturating process during roll changes. The liquid asphalt at 205 to 232°C (400 to 450°F) is sprayed on one side of the felt. This spray of hot asphalt drives moisture in the felt out the unsprayed side and prevents the moisture from forming blisters when the felt is saturated. After being sprayed, the felt passes through a tank of hot asphalt that saturates the felt. The saturated felt then enters the wet looper where it passes over another set of rollers into long vertical loops to permit cooling of the asphalt. The web of saturated felt is then rolled up from the discharge end of the wet looper either for use as roofing felt or building paper, or (after applying a small quantity of bituminous material and mica schist or rock granules--sand--to the surface) as composition roofing paper and shingles. Figure 6 is a flow diagram of an asphalt roofing saturator.[3]

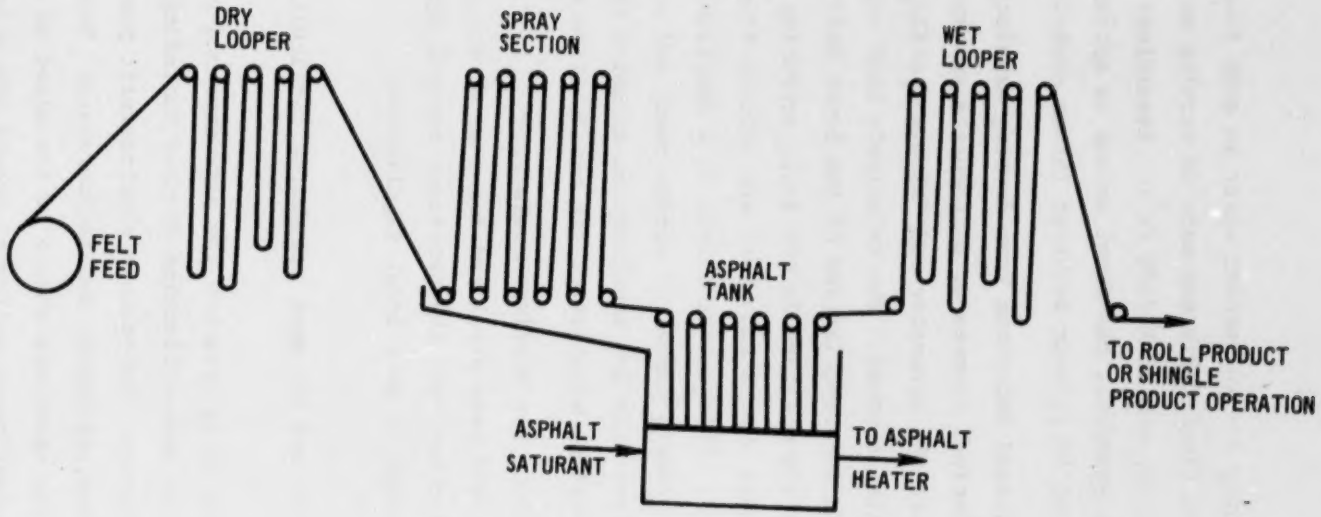

Figure 6. Flow diagram of an asphalt roofing felt saturator.

The felt containing 5 - 10 percent water is made from fibrous vegetable matter. The final felts are made in varying weights: 7, 14, and 25 kg/0.9 m^2 (15, 30, and 55 lb/100 ft^2). Regardless of the weight of the asphalt saturant, the final makeup is approximately 40 percent dry felt and 60 percent saturant (blown asphalt).

Major Sources of Pollutant Emissions from Roofing Manufacture

Although the principal sources of particulate emissions from roofing manufacture are the saturator and "blowing" stills, all operations are potential sources. The relatively high application temperature results in the vaporization of the lower boiling components of the asphalt and of the moisture in the felt, producing a highly opaque mist. Additional vapors and mists are emitted from the saturated felt in the wet looper. This emission rate is a function of felt feed rate, felt moisture content, number of sprays used, and asphalt temperature.[3] Limited test data are available on emission rates, and emission totals for roofing manufacture are conservative estimates.

Available Control Methods for Roofing Manufacture

Control methods have been developed for some of the pollutants from asphalt roofing manufacture, but the necessary control equipment has not been installed except to meet local regulations.

Particulates

Although emissions may not meet standards, particulates can be controlled by:

1. Enclosing the spray area and the saturator and ventilating through one or more collection devices including combinations of two-stage low-voltage electrostatic precipitators, fabric filters, scrubbers, and incinerators. Hoods for collecting the emissions should be installed so that there is a single continuous enclosure around the points of emission, extending down to the floor. Since operating personnel must have access to the saturator for operating adjustments, doorways or other entry provisions in the hood must usually be supplied. These should be kept as small as possible.

In addition, openings in the hoods must be provided for the entrance of felt and exit of the saturated material. These openings should be as close to the floor as possible. Experience indicates that a minimum indraft velocity of 60 m/min (200 ft/min) is required at all hood openings. Air volumes handled by the exhaust system vary with hood design and saturator size but are about 283-566 $stdm^3$/min (10,000-20,000 scfm). The large volume of air required in controlling the saturator equipment generally makes incineration impractical.(3)

2. Using electrostatic precipitators. The low-voltage (or two-stage) electrostatic precipitator, preceded by a spray scrubber as a pre-cleaner, gives relatively high collection efficiency as well as substantial reduction in the opacity of the saturator effluent.
3. Using fabric filters or baghouse filters. Baghouse filters are occasionally used as air pollution control devices for asphalt saturators, but their use is limited as a result of maintenance problems associated with filter bag upkeep and their high power requirements. Oil collected by the filter fabric is oxidized and polymerized by the air stream, plugging the fabric and increasing the pressure drop across the filter unit. The air volume handled by the exhaust system then decreases because of increased pressure drop, resulting in loss of mist capture at the saturator hood openings.(6)
4. Using scrubbers. Spray-type scrubbers have met with limited success as air pollution control devices for saturators. Although some spray scrubbers may have an efficiency, based on weight removed, as high as 90 percent, their effluent may be from 50 to 100 percent opaque. This opaque discharge is due to the extremely low collection efficiency

of spray scrubbers for particles less than 1 micron in diameter. These small-diameter particles, when emitted from the scrubber discharge, cause maximum light scattering and, therefore, high opacities.[6]

Sulfur Dioxide and Nitrogen Oxides

Limited efforts have been made to control these pollutants: scrubbers to control particulates, and using low-sulfur fuel for heating. Proper burner design and efficient operation of the heating system will greatly reduce these pollutants.

Odors and Hydrocarbons

Effluents from asphalt airblowing stills have been controlled by scrubbing and incineration, singly or in combination. Most installations use the combination. Potential air pollutants can be removed from asphalt still gases by scrubbing alone. One effective control installation in Los Angeles County uses sea water for single-pass scrubbing of effluent gases from four asphalt airblowing stills. The fume scrubber is a standard venturi-type unit. The scrubber effluent is discharged into an enclosed oil/water gravity-type separator for recovery of oil, which is reprocessed or used as fuel. Effluent gases from the covered separator that collects the scrubber discharge are not incinerated but flow through a steam-blanketed stack to the atmosphere. The system, Figure 7, removes essentially all potential air pollutants from the effluent stream. A limiting factor in the application of this method of control is the water supply. Since a high water/vapor scrubbing ratio (379 liters/28 $stdm^3$ --100 gal/1000 scf) is necessary, an economical source of water should be readily available to supply the large volume required for single-pass operation.[3]

Control Technology Needed for Roofing Manufacture

Pollutant control methods are available to asphalt roofing manufacturers. Improvement of odor control is needed. The odor study is expected to be underway by EPA in the near future.

Roofing manufacturers have not been as aggressive as hot-mix plant operators in combating air pollution due perhaps to the former's smaller production and older plants. As stated, control technology is available; it is a question of installing available equipment.

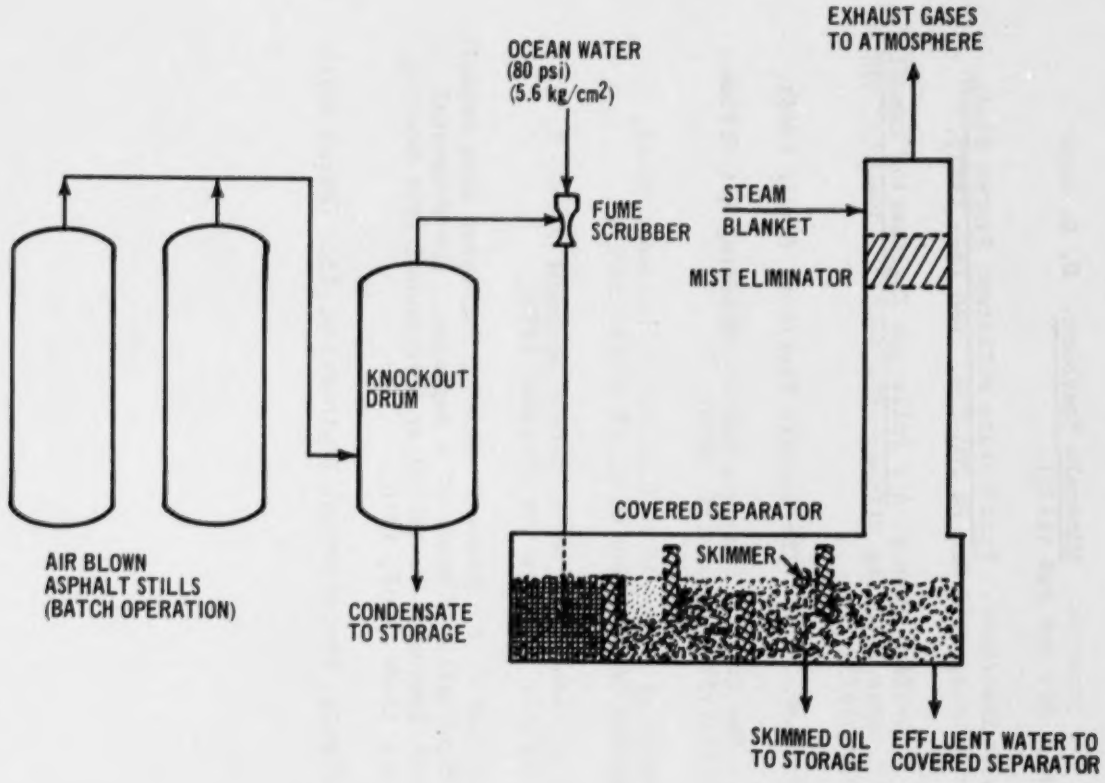

Figure 7. Flow diagram of scrubbing system.

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Appendix A (4)
TERMS RELATING TO ASPHALTIC MATERIALS

Asphalt - A dark-brown to black cementitious material (solid, semi-solid, or liquid in consistency) in which the predominating constituents are bitumens which occur in nature as such or which are obtained as residue in refining petroleum. Asphalt is a constituent in varying proportions of most crude petroleums.

Asphalt Blocks - Asphalt concrete molded under high pressure. The type of aggregate mixture composition, amount and type of asphalt, and the size and thickness of the blocks may be varied to suit usage requirements.

Asphalt, Blown or Oxidized - Asphalt that is treated by blowing air through it at elevated temperature to give it characteristics desired for certain special uses such as roofing, pipe coating, undersealing portland cement concrete pavements, membrane envelopes, and hydraulic applications.

Asphalt, Catalytically Blown - An air-blown asphalt produced by using a catalyst during the blowing process.

Asphalt Cement - Asphalt that is refined to meet specifications for paving, industrial, and special purposes.

Asphalt, Cutback - See Asphalt, Liquid, A, below.

Asphalt, Emulsified - See Asphalt, Liquid, B, below.

Asphalt, Hard - See Asphalt, Solid, below.

Asphalt Joint Filler - An asphaltic product used for filling cracks and joints in pavement and other structures.

Asphalt Joint Fillers, Preformed - Premolded strips of asphalt mixed with fine mineral substances, fibrous materials, cork, sawdust, etc.; manufactured in dimensions suitable for construction joints.

Asphalt, Lake - See Asphalt, Natural, below.

Asphalt, Liquid - An asphaltic material having a soft or fluid consistency that is beyond the range of measurement by the normal penetration test. Liquid asphalts include cutback asphalts and emulsified asphalts.

A. Cutback Asphalt - Asphalt cement which has been liquefied by blending with petroleum solvents (diluents), as for the RC and MC liquid asphalts (a and b, below). Upon exposure to atmospheric conditions the diluents evaporate, leaving the asphalt cement to perform its function.

a. Rapid-Curing (RC) Asphalt - Liquid asphalt composed of asphalt cement and a naphtha or gasoline-type diluent of high volatility.

b. Medium-Curing (MC) Asphalt - Liquid asphalt composed of asphalt cement and a kerosene-type diluent of medium volatility.

c. Slow-Curing (SC) Asphalt - Liquid asphalt composed of asphalt cement and oils of low volatility.

d. Road-Oil - A heavy petroleum oil, usually one of the SC grades of liquid asphalt.

B. Emulsified Asphalt - An emulsion of asphalt cement and water which contains a small amount of an emulsifying agent; a heterogeneous system containing two normally immiscible phases (asphalt and water) in which the water forms the continuous phase of the emulsion, and minute globules of asphalt form the discontinuous phase.

Asphalt, Medium-Curing (MC) - See Asphalt, Liquid, A.b, above.

Asphalt, Mineral-Filled - Asphalt containing finely divided mineral matter.

Asphalt, Natural (Native) - Asphalt, occurring in nature, which has been derived from petroleum by natural processes of evaporation of volatile fractions, leaving the asphalt fractions. The native asphalts of most importance are found in the Trinidad and Bermudez Lake deposits. Asphalt from these sources often is called Lake Asphalt.

Asphalt Paint - A liquid asphaltic product sometimes containing small amounts of other materials such as lampblack, aluminum flakes, and mineral pigments.

Asphalt Panels, Premolded - Generally made with a core of asphalt, minerals, and fibers, covered on each side by a layer of asphalt-impregnated felt or fabric , and coated on the outside with hot-applied asphalt. The panels are made under pressure and heat to a width of 9 to 12 meters (3 to 4 feet) by 0.3 to 2.5 cm (1/8 to 1 inch) thick, and to any desired length.

Asphalt, Petroleum - Asphalt refined from crude petroleum.

Asphalt Planks - Premolded mixtures of asphalt fiber and mineral filler, sometimes reinforced with steel or fiberglass mesh. They are usually made 9 to 24 meters (3 to 8 feet) long and 15 to 30 cm (6 to 12 inches) wide. Asphalt planks may also contain mineral grits which maintain a sandpaper texture throughout their life.

Asphalt, Powdered - Solid or hard asphalt, crushed or ground to a fine state of subdivision.

Asphalt Primer - A liquid asphalt of low viscosity which penetrates a non-bituminous surface upon application.

Asphalt, Rapid-Curing (RC) - See Asphalt, Liquid, A. a, above.

Asphalt, Rock - Porous rock, such as sandstone or limestone, that has become impregnated with natural asphalt through geologic process.

Asphalt, Semisolid - Asphalt which is intermediate in consistency between liquid asphalt and solid or hard asphalt; that is, it normally has a penetration between 10 and 300.

Asphalt, Slow-Curing (SC) - See Asphalt, Liquid, A. c, above.

Asphalt, Solid - Asphalt having a normal penetration of less than 10. Also referred to as hard asphalt.

Bitumen - A mixture of hydrocarbons of natural or pyrogenous origin, or a combination of both; frequently accompanied by nonmetallic derivatives which may be gaseous, liquid, semisolid, or solid; and which are completely soluble in carbon disulfide.

Flux Oil - A thick, relatively nonvolatile fraction of petroleum which may be used to soften asphalt to a desired consistency; often used as base stock for manufacture of roofing asphalts. Also referred to simply as flux.

Gilsonite - Trade name for a form of natural asphalt, hard and brittle, occurring in rock crevices or veins from which it is mined. Also see Uintaite, below.

Road Oil - See Asphalt, Liquid, A.d, above.

Uintaite - A black lustrous asphalt, occurring especially in Utah, that is used in the manufacture of paints, varnishes, inks, and waterproofing. Also see Gilsonite, above.

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Appendix B (4)
TERMS RELATING TO ASPHALT PAVEMENTS AND SURFACE TREATMENTS

Aggregate - Any hard, inert, mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone, and slag.

Aggregate, Coarse - That retained on the No. 8-mesh sieve.

Aggregate, Coarse-Graded - One having a continuous grading in sizes of particles from coarse through fine with a predominance of coarse sizes.

Aggregate, Fine - That passing the No. 8-mesh sieve.

Aggregate, Fine-Graded - One having a continuous grading in sizes of particles from coarse through fine with a predominance of fine sizes.

Aggregate, Macadam - A coarse aggregate of uniform size usually of crushed stone, slag, or gravel.

Aggregate, Open-Graded - One containing little or no mineral filler or in which the void spaces in the compacted aggregate are relatively large.

Aggregate, Well-Graded - Aggregate that is graded from the maximum size down to filler, used to obtain an asphalt mix with a controlled void content and high stability.

Aggregate Seals - See Asphalt Seal Coat, below.

Armor Coat Treatment - See Multiple Surface Treatments, below.

Asphalt Base Course - A foundation course consisting of mineral aggregate, bound together with asphaltic material.

Asphalt Binder Course - See Asphalt Intermediate Course, below.

Asphalt Block Pavements - Pavements in which the surface course is constructed of asphalt blocks. These blocks are laid in regular courses as in the case of brick pavements.

Asphalt Concrete - High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high quality aggregate, thoroughly compacted into a uniform dense mass.

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Asphalt Emulsion Slurry Seal - A mixture of slow-setting emulsified asphalt, fine aggregate, and mineral filler, with water added to produce slurry consistency.

Asphalt Fog Seal - A light application of liquid asphalt without mineral aggregate cover. Slow-setting asphalt emulsion diluted with water is the preferred type.

Asphalt Intermediate Course - A course between a base course and an asphalt surface course. Also called binder course.

Asphalt Leveling Course - A course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in the contour of an existing surface prior to superimposed treatment or construction.

Asphalt Macadam - A type of pavement construction using a coarse, open-graded aggregate that is usually produced by crushing and screening stone, slag, or gravel. Such aggregate is called Macadam Aggregate. Asphalt may be incorporated in macadam construction either by penetration or by mixing.

Asphalt Mastic - A mixture of asphalt and fine mineral material in such proportions that it may be poured hot or cold into place and compacted by troweling to a smooth surface.

Asphalt Overlay - One or more courses of asphalt construction on an existing pavement. The overlay generally includes a leveling course to correct the contour of the old pavement, followed by a uniform course or courses to provide needed thickness. When overlaying rigid-type pavements, the overlay should be not less than 10 cm (4 inches) thick to minimize reflection of cracks and joints through the overlay. Greater thickness of overlay may be required depending upon both the condition of the old pavement and traffic to be served.

Asphalt Pavement - Pavement consisting of a surface course of mineral aggregate coated and cemented together with asphalt cement on supporting courses such as asphalt bases; crushed stone, slag, or gravel; or on portland cement concrete, brick, or block pavement.

Asphalt Pavement Structure - Courses of asphalt/aggregate mixtures, plus any non-rigid courses between the asphalt construction and the foundation or subgrade. The term "flexible," sometimes used in connection with asphalt pavements, denotes the ability of such a pavement structure to conform to settlement of the foundation. Also called flexible pavement structure.

Asphalt Prime Coat - An application of low-viscosity liquid asphalt to an absorbent surface. It is used to prepare an untreated base for an asphalt surface. The prime penetrates the base and plugs the

voids, hardens the top, and helps bind it to the overlying asphalt course. It also reduces the necessity of maintaining an untreated base course prior to placing the asphalt pavement.

Asphalt, Sand - A mixture of sand and asphalt cement or liquid asphalt prepared with or without special control of aggregate grading with or without mineral filler. Either mixed-in-place or plant-mix construction may be employed. Sand asphalt is used in construction of both base and surface courses.

Asphalt Seal Coat - A thin asphalt surface treatment used to waterproof and improve the texture of an asphalt wearing surface. Depending on purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are aggregate seals, fog seals, emulsion slurry seals,and sand seals.

Asphalt, Sheet - A hot mix of asphalt cement with clean angular, graded sand and mineral filler. Its use is ordinarily confined to surface course, usually laid on an intermediate or leveling course.

Asphalt Soil Stabilization (Soil Treatment) - Treatment of naturally occurring non-plastic or moderately plastic soil with liquid asphalt at normal temperatures. After mixing, aeration and compaction provide water resistant base and subbase courses of improved load bearing qualities.

Asphalt Surface Course - The top course of an asphalt pavement, sometimes called asphalt wearing course.

Asphalt Surface Treatment - Application of asphaltic materials to any type of road or pavement surface, with or without a cover of mineral aggregate, which produces an increase in thickness of less than 2.54 cm (1 inch).

Asphalt Tack Coat - A very light application of liquid asphalt applied to an existing asphalt or portland cement concrete surface. Asphalt emulsion diluted with water is the preferred type. It is used to ensure a bond between the surface being paved and the overlying course.

Asphalt Wearing Course - See Asphalt Surface Course, above.

Base Course - The layer of material immediately beneath the surface or intermediate course. It may be composed of crushed stone, crushed slag, crushed or uncrushed gravel and sand, or combinations of these materials. It also may be bound with asphalt.

Basement Soil - See Subgrade Soil, below.

Cold-Laid Plant Mixture - Plant mixes which may be spread and compacted at atmospheric temperature.

Deep-Lift Asphalt Pavement - One in which the asphalt base course is placed in one or more lifts of 10 cm (4 inches) or more compacted thickness.

Deep-Strength - A term registered by The Asphalt Institute with U. S. Patent Office. The term Deep-Strength (also called "mark") certifies that the pavement is constructed of asphalt with an asphalt surface on an asphalt base and in accordance with design concepts established by the Institute.

Dry Sieve Analysis - See Sieve Analysis, below.

Emulsion Slurry Seals - See Asphalt Seal Coat, above.

Flexible Pavement Structure - See Asphalt Pavement Structure, above.

Fog Seals - See Asphalt Seal Coat, above.

Foundation Soil - See Subgrade Soil, below.

Full-Depth Asphalt Pavement - One in which asphalt mixtures are used for all courses above the subgrade or improved subgrade. It is laid directly on the prepared subgrade. (The mathematical symbol Ta denotes full-depth or total asphalt.)

Hot-Laid Plant Mixture - Plant mixes which must be spread and compacted while at an elevated temperature. To dry the aggregate and obtain sufficient fluidity of the asphalt (usually asphalt cement), both must be heated prior to mixing, giving origin to the term "hot mix."

Inverted Penetration Treatment - See Multiple Surface Treatments, below.

Macadam Aggregate - See Asphalt Macadam, above.

Mineral Dust - The portion of the fine aggregate passing the No. 200-mesh sieve.

Mineral Filler - A finely divided mineral product at least 65 percent of which will pass a No. 200-mesh sieve. Pulverized limestone is the most commonly manufactured filler; although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

Mixed-in-Place - An asphalt course produced by mixing mineral aggregate and liquid asphalt at the road site by means of travel plants, motor graders, drags, or special road-mixing equipment. Also called road mix.

Multiple Lift Treatment - See Multiple Surface Treatments, below.

Multiple Surface Treatments - Commonly two or three successive applications of asphaltic material and mineral aggregate. (Treatments designated "Armor Coat," "Multiple Lift," and "Inverted Penetration" are essentially multiple surface treatments.)

Pavement Structure - All courses of selected material placed on the foundation or subgrade soil, other than layers or courses constructed in grading operations.

Pavement Structure, Combination (or Composite) Type - When the asphalt pavement is on an old portland cement concrete base, or other rigid-type base, the pavement structure is referred to as a combination (or composite) type pavement structure.

Penetration - The penetration test determines the relative hardness or consistency of an asphalt cement by measuring the distance that a standard needle will penetrate vertically into a sample of asphalt under known conditions of temperature, loading, and time. When other conditions are not specifically mentioned, it is understood that penetration value or measurement is made at 25°C (77°F); that the needle is loaded to 100 grams; and that the load is applied for 5 seconds. This is known as standard penetration. The unit of penetration is 1/10 mm (about 1/254 inch). It is evident that the softer asphalt cement will have a greater number of penetration units. Using penetration limits, asphalt cements are classified on the basis of hardness or consistency. The Asphalt Institute has adopted four grades of asphalt cement for paving, with penetration ranges of 60-70, 85-100, 120-150, and 200-300. The Institute also has specifications for a 40-50 penetration grade, used for special and industrial purposes.

Plant Mix - A mixture, produced in an asphalt mixing plant, which consists of mineral aggregate uniformly coated with asphalt cement or liquid asphalt.

Road-Mix - See Mixed-in-Place, above.

Rock Asphalt Pavement - Pavement constructed of rock asphalt, natural or processed, and treated with asphalt or flux.

Sand Seals - See Asphalt Seal Coat, above.

Sieve Analysis - There are two methods of determining the relative proportions of various particle sizes in a mineral aggregate: dry sieve analysis, and washed sieve analysis.

A. Dry Sieve Analysis - A weighed quantity of thoroughly dried aggregate is shaken over a set of sieves each with different sizes of square openings. The sieves are nested together: the one with the largest opening is on top; and those with successively smaller openings are below it. A pan under the bottom sieve collects all material passing

through it. The shaking is normally accomplished with a mechanical sieve shaker. The weight of material retained on each sieve size is expressed as a percentage of the weight of the original or total sample. Commonly used with asphalt paving mixes are 6.4, 5.1, 3.8, 2.5, 1.9, 1.3, and 1.0 cm (2-1/2, 2, 1-1/2, 1, 3/4-, 1/2-, and 3/8-inch) square opening mesh sieves and No. 4-, 8-, 16-, 30-, 50-, 100-, and 200-mesh sieves.

B. Washed Sieve Analysis - This method of testing determines the particle size distribution of fine and coarse aggregates by washing. This method should always be used if the aggregate contains extremely fine dust, or clay which may cling to the coarser aggregate particles. In such instances, results using dry sieve analysis will be in error.

Subbase - The course in the asphalt pavement structure immediately below the base course is called the subbase. If the subgrade soil is of adequate quality it may serve as the subbase.

Subgrade Soil - The uppermost material placed in embankments or not removed from cuts in the normal roadbed grading. It is the foundation for the asphalt pavement structure. Subgrade soil sometimes is called basement or foundation soil.

Subgrade, Improved - Any course or courses of select or improved material between the foundation soil and the subbase is usually referred to as the improved subgrade. The improved subgrade can be made up of two or more courses of different quality materials.

Washed Sieve Analysis - See Sieve Analysis, above.